



712CD 75TH MORSS CD Cover Page

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59th Test and Evaluation Squadron

Resampling Statistics for the F-22A Lot 5 Suitability Analysis



**Mr. Juan P Perez
59 TES/EAA**

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59th TES Operations



- ❖ 59th TES in conjunction with 422nd TES
 - Perform Operational Test & Evaluation (OT&E)
 - Tactics Development
 - Fielding Recommendations
- ❖ Weapon Systems
 - A-10, F-15C, F-15E, F-16, F-22A, HH-60





Purpose



- ❖ Explain the problem
- ❖ Demonstrate the Resampling Technique
 - Construct the Cumulative Distribution Function (CDF)
 - Build a Confidence Interval
 - Calculate Power/Consumer Risk
- ❖ Demonstrate application tool used for the suitability analysis



Overview



- ❖ **Test Problem**
- ❖ **Background**
- ❖ **Test Objective**
- ❖ **Test Methodology**
- ❖ **Reporting**
- ❖ **Conclusion**



Test Problem: Lot 5 System Description



Advanced Radar Program PIP B171 & DO-03



IPFA



Radar
Antenna

New S/W
for Lot 5 &
Sp 2



Radar
Receiver
Exciter



Radar
Processor



HUD
DMS & PIP
New S/W for
Sp 2 & Lot 5



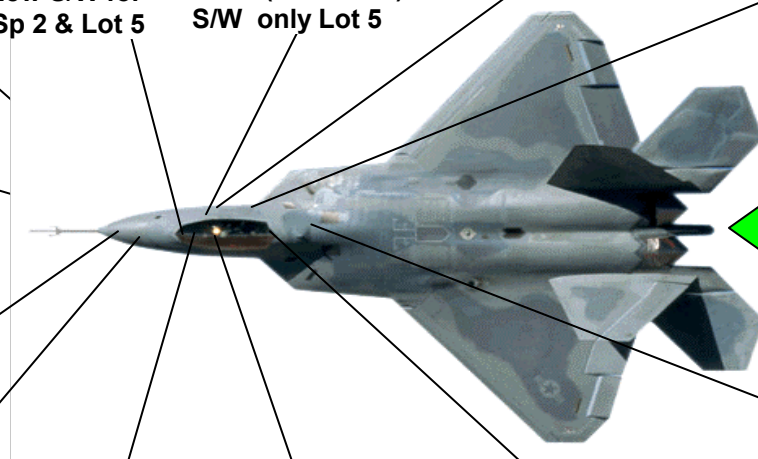
Aux Com/ACP
PIP211 (Lot 6 H/W)
S/W only Lot 5



IFDL Controller
PIP212



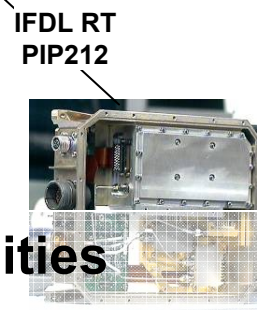
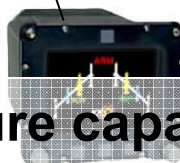
DEW
PIP209A
New L5 S/W



DMVR
DMS

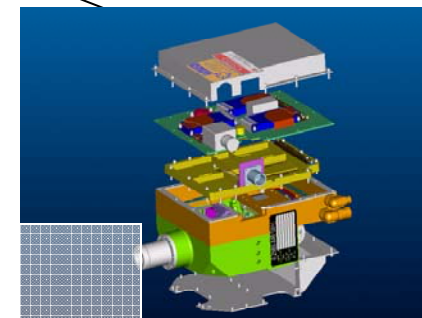


UFD
DMS & PIP
New L5 S/W



IFDL RT
PIP212

MLD Sensor
PIP238FGA



OFP 3.1.3 L5
Functionality
Equivalent to Lot
3 Production
Aircraft

• Enhance radar's future capabilities

• New contractor building "same" parts



Test Problem: F-22A Lot 5 Suitability Analysis



- ❖ **Test's Purpose: To compare currently fielded aircraft suitability results to Lot 5 aircraft.**
 - Operational Utility Evaluation (OUE): compare effectiveness and suitability between F-22A Lot 5 aircraft (new data set) and currently fielded F-22A aircraft (baseline data set)
 - Suitability goal: evaluate Lot 5 hardware updates only
 - Suitability structure: compare data using Reliability, Maintainability and Availability (RM&A).



Test Problem: F-22A Lot 5 Suitability Analysis



❖ **Analyst's Challenge: How to compare current suitability results to new Lot 5 suitability measures?**

- Baseline data (currently fielded aircraft) includes 758 flight hours. Lot 5 test has shorter timeline requirements.
- The test requires a minimum 70% power / 30% consumer risk in detecting at least a doubling (twice as bad) in any suitability measure.
- The new test consists of 200 flight hours



Overview



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Background: Suitability



- ❖ Operational suitability: the degree to which a system can be satisfactorily placed into fielded use
 - reliability, maintainability, availability (RM&A)
- ❖ Availability: affected by reliability and maintainability
- ❖ Other considerations: compatibility, transportability, wartime usage rates, safety, human factors, manpower supportability, logistics supportability, documentation, training requirements, and natural environmental effects and impacts



Background: Suitability



- ❖ Reliability: the probability of a system to perform its function [3]
 - Time-continuous: operate the system until it fails, fix it and continue to operate. Process repeats until enough information is collected
 - Success/Fail: test the system and record successes and failures
- ❖ Maintainability: the ability of an item to be retained in, or restored to, a specified conditions when maintenance is performed (AFI 10-602)
 - Average time between maintenance activity
 - Cumulative maintenance time divided by flying hours
- ❖ Availability: the probability that a system will be in an operable state at a random point in time [3]
 - Operational time divided by the total time



Background: Suitability Analysis



❖ Reliability, Maintainability and Availability Evaluation

➤ New Lot 5 hardware data collection only

➤ Test scoring data Measures of Performance (MOP):

- ✓ Break rate
- ✓ Mean time between critical failure (MTBCF)
- ✓ Could not duplicate rate
- ✓ Maintenance man hours per flying hour
- ✓ 2/4/8 hour fix rate
- ✓ Abort rate
- ✓ Mean time between maintenance
- ✓ Weapons system reliability
- ✓ Integrated diagnostics accuracy
- ✓ Mean down time
- ✓ Mean repair time

$$MTBCF = \frac{\text{Total Flying Hours}}{\text{Number of Critical Failures}}$$



Background: Resampling



What is Resampling?

- ❖ Mechanism used to produce a hypothetical distribution by randomly taking samples from an observed distribution or baseline distribution
- ❖ Essentially: Monte Carlo simulation of statistical results
- ❖ Basic Rules:
 1. Specify the universe to sample from
 - ✓ observed data set or baseline data set
 2. Specify the sampling procedure
 - ✓ number of samples
 - ✓ sizes of samples
 - ✓ sampling with or without replacement
 3. Specify the statistic you wish to keep track of
 - ✓ ratio, mean, variance, etc.



Background: Resampling



❖ Advantages

- Simple to use and teach
- Avoids using the wrong method
- Knowledge of distribution not needed
- Free of mathematical formulas and restrictive assumptions

❖ Disadvantages

- Requires empirical data
- Sample size can be a problem if the baseline data is limited



Overview



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Test Objective: F-22A Lot 5 Suitability Analysis



- ❖ Assess operational effectiveness of new Lot 5 hardware
- ❖ Compare Lot 5 hardware and equivalent hardware for currently fielded aircraft suitability
 - Report results outside a 90% confidence bound as significantly different
 - If not significantly different, report power/consumer risk
 - The formal hypothesis for each MOP for this approach is as follows:

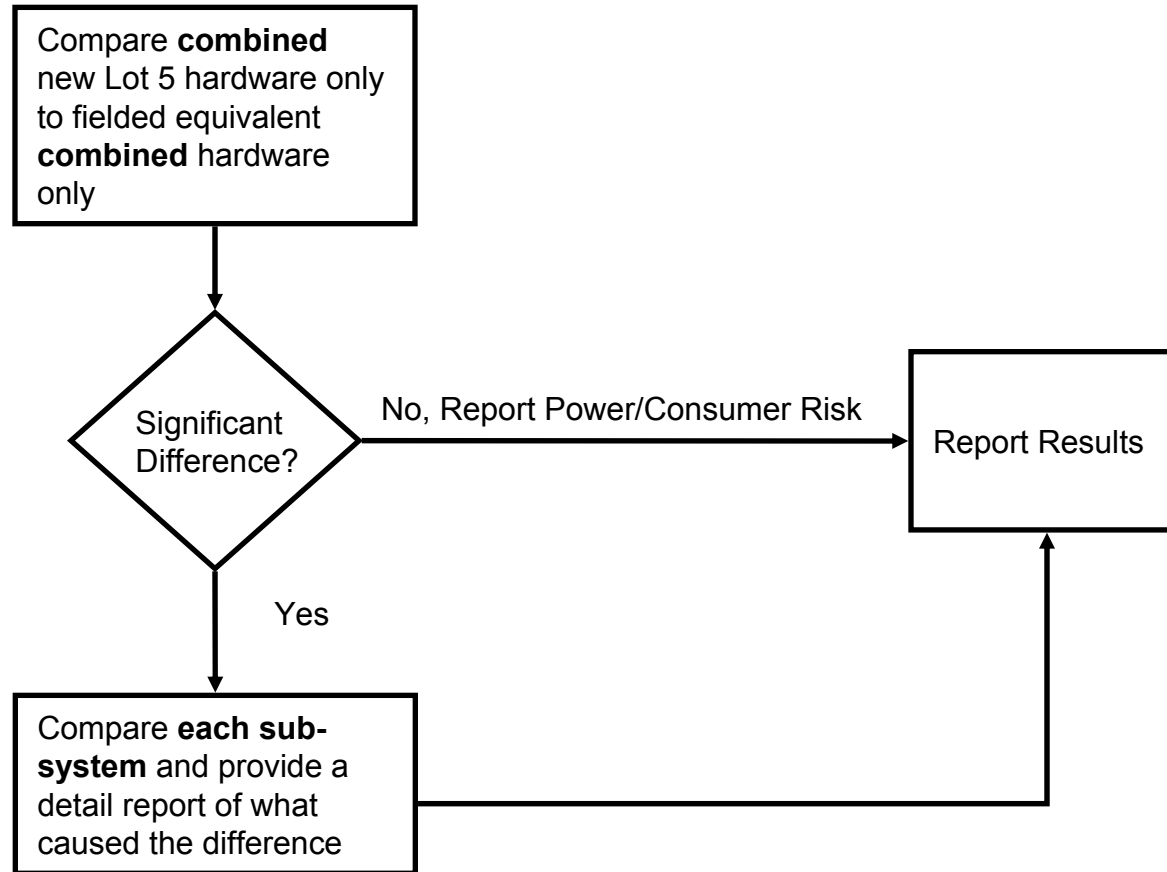
$$H_o : \text{Lot 5 MOP} \geq \text{FDE MOP}$$

$$H_1 : \text{Lot 5 MOP} < \text{FDE MOP} (\alpha = .1)$$

** Note: hypothesis assumes that a larger value is better



Test Objective: Algorithm



Repeat flow for each suitability MOP



Overview



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Test Methodology: Example



Mean Time Between Critical Failure (MTBCF)

$$\text{MTBCF} = \frac{\text{Total Flight Hours}}{\text{Number of Critical Failures}}$$

- ❖ The suitability study for currently fielded aircraft recorded 18 critical failures (CF) during 758 hours of operation for a MTBCF of 42.11
- ❖ Create a representative population using 758 binary values
 - Assume 1 sample per flying hour
 - Assign a '1' to CFs (18 occurrences)
 - Assign a '0' to no CFs (740 occurrences)
- ❖ Use resampling to produce a 200 hour representative (hypothetical) population
- ❖ Construct a CDF of the 200 hour MTBCF
- ❖ Use the CDF of the 200 hour data to find the lower 90% confidence bound



Test Methodology: Test Model



- ❖ Compare the new set of performance data (Lot 5) to Cumulative Distribution Function of the established baseline (currently fielded aircraft)
- ✓ Resampled Score must be fielded hours with a 90% lower confidence bound
- ❖ This provides representative population

Report Structure: Independent Samples

Use the Ctrl key to enter non-contiguous cells. You may also type in cell or range addresses. Use the comma (,) to separate individual or non-contiguous cells or ranges. Use the / to separate sheets.

Sheet3!\$H\$6

Iterations: 1000 Number of Trials

Display: ☐ Disable Screen Updating (Faster Execution)

Output Sheet: ☒ Overwrite Previous Output Data

©2005 Resampling Stats, Inc. Written by Stan Blank, PhD
Contact us at 703-522-2713 or stats@resample.com

sample from

FH)

hour

cedure

replacement

wish to keep track of

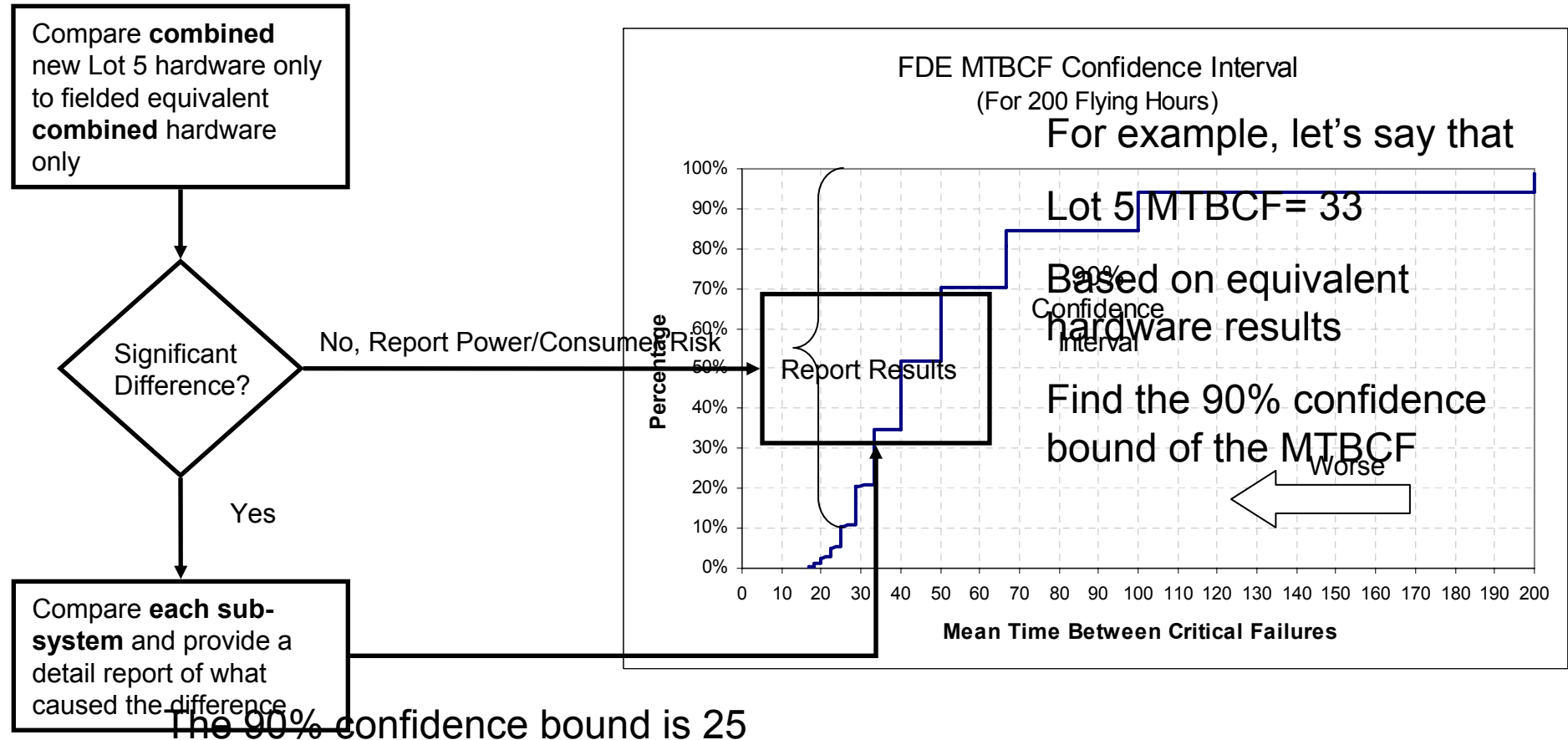
	A	B	C	D	E
2	Resampled Results				
3	1	15.38	0.002		
4	2	15.38	0.003		
5	3	15.38	0.004		
6	4	15.38	0.005		
7	5	15.38	0.006		
8	6	16.67	0.007		
9	7	16.67	0.008		
10	8	18.18	0.009		
11	9	18.18	0.010		
12	10	18.18	0.011		
13	11	18.18	0.012		
14	12	18.18	0.013		
15	13	18.18	0.014		
16	14	18.18	0.015		
17	15	18.18	0.016		
18	16	18.18	0.017		
19	17	20.00	0.018		
20	18	20.00	0.019		
21	19	20.00	0.020		
22	20	20.00	0.021		
23	21	20.00	0.022		
24	22	20.00	0.023		
25	23	20.00	0.024		
26	24	20.00	0.025		
27	25	20.00	0.026		
28	26	20.00	0.027		
29	27	20.00	0.028		
30	28	20.00			

	G
	MTBCF
	40

740
No
CFs



Test Methodology: Confidence Interval



33 is in the 90% of the data, therefore there is no significant difference between Lot 5 and the currently fielded hardware



Test Methodology: MTBCF Power



- ❖ CDF constructed using resampling statistics
- ❖ Use resampled results to calculate power
- ❖ Power indicates the confidence level the test design provides to detect a particular level of increase in the MTBCF based on possible results

	Null hypothesis is True	Null hypothesis is false
Reject the null hypothesis	Type I error (rejecting a true null hypothesis) α	Correct decision
Fail to reject the null hypothesis	Correct decision	Type II error (failing to reject a false null hypothesis) β



Test Methodology: Power (Classical Method)



- ❖ Classical method: theory based
- ❖ Resampling method: observation based
- ❖ An example to demonstrate the classical method
 - Measuring successes and failures, therefore use the binomial distribution
 - Probability Mass Function: PMF

The binomdist excel function provides the CDF/PMF of the binomial distribution

Function → BINOMDIST(# success, trials, probability of success, cumulative)

Number of success → (Trials-CF)

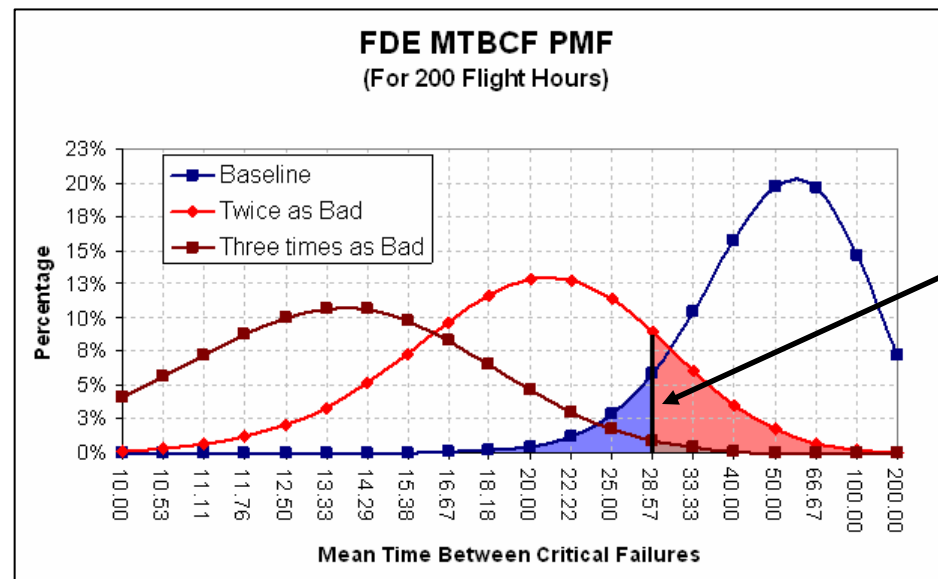
Trials → Total Flight Hours

Probability → (Trials-CF)/Trials

Cumulative → TRUE provides the CDF; FALSE provides the PMF



Test Methodology: Power (Classical Method)



90%
confidence
bound

- ❖ The PMF (blue) was generated based on the known baseline(758FH with 18 CFs)
- ❖ The red PMF – Distribution is twice as bad as the main baseline
- ❖ The blue PMF – Distribution is three times a bad as the main baseline
- ❖ Any results outside the 90% (lower than 28.57 MTBCF) will be considered significantly different.



Test Methodology: MTBCF Power (Resampling)



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	CF	5	8	10	12	15															
2	MTBCF	40	25	20	16.67	13.33															
3																					
4	Unknown Distribution																				
5	200 FH / 10 CFs				200 Hrs Resampled	MTBCF															
6	1				0																
7	1				0																
8	1				0																
9	1				0																
10	1				0																
11	1				0																
12	1				0																
13	1				0																
14	1				0																
15	1				0																
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24	0				0																
25	0				0																
26	0				0																
27	0				0																
28	0				0																
29	0				0																

Resampled Results

1	10.00	0.001
2	10.00	0.002
3	10.53	0.003
4	10.53	0.004
5	11.11	0.005
6	11.11	0.006
7	11.11	0.007
:	:	:
774	25	0.774
775	25	0.775
776	28.57143	0.776
777	28.57143	0.777
:	:	:
863	28.57143	0.863
864	33.33333	0.864
865	33.33333	0.865
:	:	:
933	33.33333	0.933
934	40	0.934
935	40	0.935
:	:	:
986	50	0.986
987	50	0.987
988	66.66667	0.988
:	:	:
997	66.66667	0.997
998	100	0.998

MTBCF Power for 200 hrs

MTBCF Results	Actual (Unknown) MTBCF			
	25	20	16.7	13.33
100	98.7%	99.7%	99.9%	99.9%
67	96.7%	98.7%	99.9%	99.9%
40	80.8%	93.3%	98.2%	99.8%
33	66.7%	86.3%	95.9%	99.1%
28.57	40.2%	77.5%	84.8%	97.3%



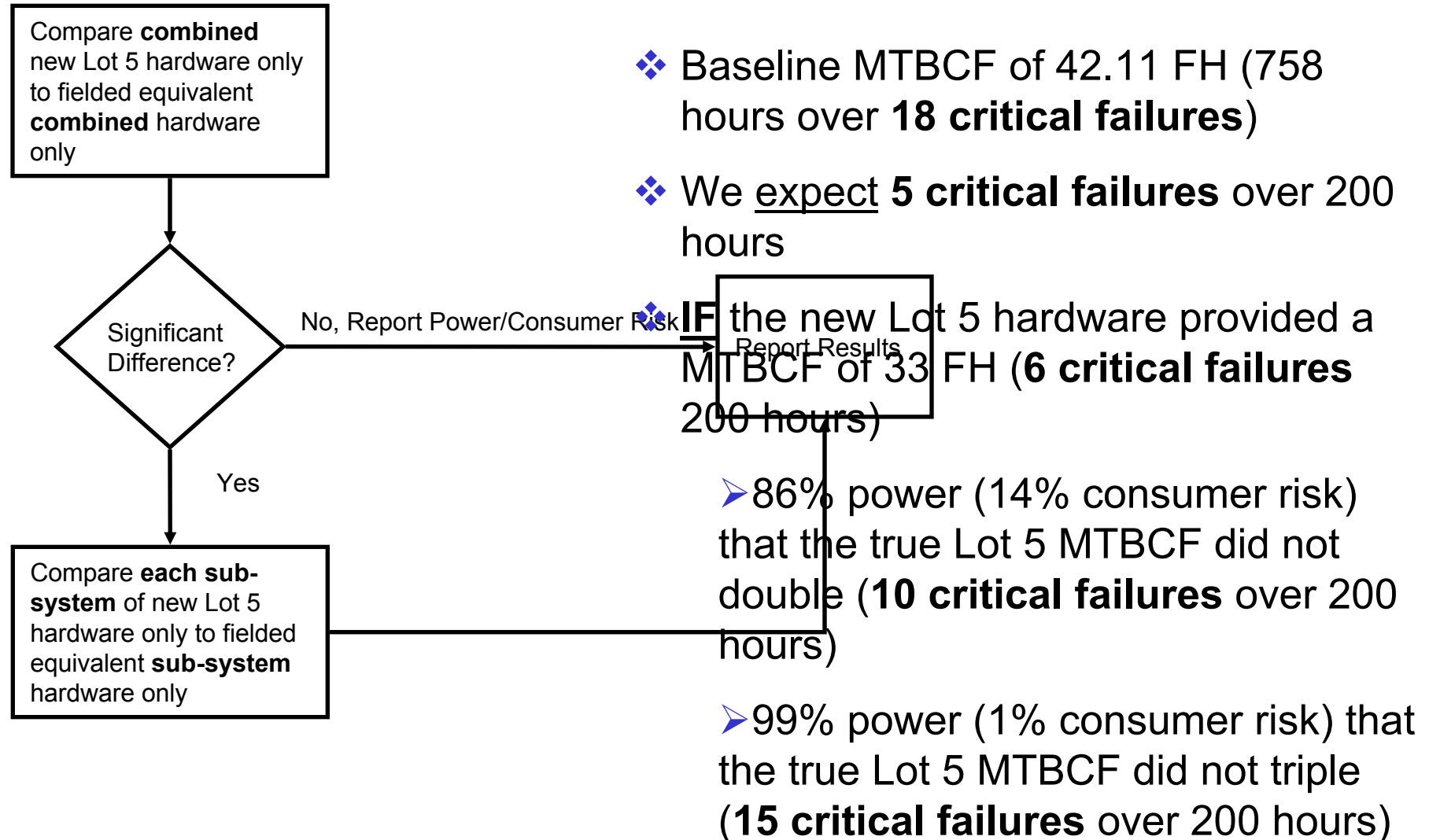
Overview



- ❖ **Test**
- ❖ **Background**
- ❖ **Test Objective**
- ❖ **Test Methodology**
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- ❖ **Conclusion**



Report Results





Overview



- ❖ **Test**
- ❖ **Background**
- ❖ **Test Design**
- ❖ **Test Methodology**
- ❖ **Reporting**
- ❖ **Conclusion**



Conclusion



- ❖ Resampling Statistics makes possible:
 - Construction of CDFs
 - Building Confidence Intervals
 - Calculating Power/Consumer Risk
- ❖ Resampling Statistics with F-22A Lot 5 suitability:
 - Facilitates comparison between large baseline sample size and small test sample size
 - Provides method to compute power
 - Evaluates data without knowledge of the distribution
 - Eliminates mathematical formulas and restrictive assumptions



References



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<http://www.resample.com/>

59th Test and Evaluation Squadron

Questions?



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